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DRY WEIGHT AND MINERAL COMPOSITION ESTIMATES FOR 15 YEAR OLD MIXED HARDWOOD COPPICE IN ROUDSEA WOOD

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Introduction

Measurements of primary and secondary production have recently been made in Meathop Wood as part of the UK contribution to the International Biological Programme. Meathop Wood, a mixed deciduous woodland situated on an outcrop of Carboniferous limestone near the shore of Morecambe Bay, was formerly managed under a coppice system and it has been suggested that regular removal of young coppice shoots may have led to a depletion of mineral nutrients at the site. The length of a coppice cycle varies between species and between areas but in the southern Lake District it is thought to have been approximately fifteen years. Coppice management at Meathop lapsed many years ago and it has therefore not been possible to obtain good evidence of the likely effect of coppice removal on nutrient reserves at the site. The purpose of the present study was to locate a coppice stand of similar composition growing under similar conditions to those existing at Meathop Wood, but of younger age, and to estimate the quantities of nutrient elements which would be removed from the site in coppice working.

One of the few accessible sites in the vicinity where there is relatively young coppice-wood growing on limestone is at Roudsea Wood. Even here the coppice growth was 27 years old and was not therefore entirely suitable. Moreover, the situation was complicated by the fact that a first singling of ash and oak stools had taken place five years previous to the study. Nevertheless it was considered that useful information could be obtained relating to the present mineral nutrient concentrations in the coppice wood and that crude estimates could be made of their likely levels when the wood was fifteen years old.

Site description

Roudsea Wood is situated on the eastern bank of the estuary of the River Leven which runs into Morecambe Bay. The wood is on the edge of the Lake District National Park and is a National Nature Reserve.

The sample plot (NGR 334818) was situated on a small ridge running north/south and lay between the 25' and 50' contour lines. The ridge is of Carboniferous limestone and nearly half the plot contained exposed limestone pavement with brown earth soils filling the grikes. The rest of the plot was totally covered with soil which in the wood in general has a pH of 6.0-7.5 (Bunce, 1968).

All the trees on the plot were of coppice origin and there were no true standards. The main species were oak (Quercus robur) and ash (Fraxinus excelsior) with an extensive shrub layer of hazel (Corylus avellana). The ground flora was dominated by Dog's Mercury (Mercurialis perennis) and Wood false-brome (Brachypodium sylvaticum).

Records are scarce concerning the past management of the compartment containing the plot, but it is thought that the area was commercially coppiced regularly until the early 1940's, and the oak and ash have been thinned out at least once since then.

General method

A subjectively representative area was selected and a square sample plot of 0.1 acre was established. All coppice stools were labelled and an inventory made of those stems which had reached breast height (1.3 m). Diameters of stumps remaining from the singling operation carried out five years previously were measured. Frequencies of stem diameter classes occurring in the various stool sizes were calculated for oak, ash and hazel and samples for felling were allocated in such a way that all diameters and stool sizes were represented in the sample. Twelve stems of both oak and ash, and thirty stems of hazel were felled in April 1973, before bud-break, approximating to the time of a normal coppice cut. After felling, the height of each stem was measured and the diameters at 1.3 m and at stem base were recorded. Each stem was then cut at intervals of 2 cm diameter along its length from the base until it reached a diameter of 4 cm and thereafter at 1 cm diameter intervals. The resulting sections were weighed to the nearest gram and recorded. A basal disk was removed from each section and weighed to 0.1 g. These disks were taken back to the laboratory but the remainder of the section was left on the site. All material less than 1 cm in diameter was weighed together and one complete branch taken as a sample. All dead wood was weighed together irrespective of size, and a sample taken.

All samples were dried at 105°C for four days. A test showed that further weight loss after another two days was only about 1% which, when compared with the precision of the weighing, was acceptable. All samples were cooled in a desiccator and reweighed.

The dry weight:fresh weight ratio of the samples was used to obtain the dry weight of each section.

The sample disks for each species were split into quarters, one of which was bulked with other quarters of the same diameter from other trees; this was repeated with one other set of quarters. The two duplicate sets, each having several samples per diameter class, were ground using a 0.7 mm sieve, and analysed for concentrations of Na, K, Ca, Mg, P, N.

Biomass and mineral content at age 27 i.e. 1973

The stand consisted of three principal species, oak, ash and hazel together with very scattered spindle and hawthorn which were ignored for the present purpose. The 37 oak stems had a mean diameter of 7.5 cm, the 42 ash stems had a mean diameter of 6.4 cm and the 408 hazel stems a mean diameter of 3.0 cm. The frequency of stem diameters is presented in Fig. 1. Basal areas were as follows: oak 4.7 m^2/ha, ash 3.8 m^2/ha and hazel 9.1 m^2/ha.

Biomass estimates for the three species were derived using the well-established allometric relationship between dry weight and stem diameter. Regressions of weight on diameter were calculated separately for each species, according to the equation

$$\log_e W = a + b. \log_e x$$

where W = stem dry weight in g, x = stem diameter at 1.3 m in cm and where a and b are the regression constant and coefficient respectively.

The statistics for these regressions are presented in Table 1 and the corresponding scatter diagrams in Fig. 2. From the inventory of stem diameters taken in 1973, predictions of individual stem weights were made and were summed using the procedures described by Mountford and Bunce (1973).

Biomass estimates for the three species are shown in Table 2a, together with their 95% confidence intervals. Oak, ash and hazel contributed 31.7%, 27.6% and 40.7% to the total biomass of the stand which was 47,600 kg/ha.

Chemical analyses of the disk segments for six major elements are presented as percentage dry weight of the various sizes of stem sections for oak, ash and hazel in Table 3. Apart from the expected higher concentrations of all elements in the smallest size class, presumably resulting from higher bark proportion and the presence of buds, other notable features are the high concentration of potassium in ash and of calcium in the larger sizes of oak.

For each sample stem, element concentration was multiplied by the dry weight of each stem section and hence the total weight of elements in every sample stem was derived. Regressions relating the weight of each element to stem diameter were calculated for the three species, details of which are presented in Table 4 and Fig. 3. Aberrant results for sodium are caused by many concentrations being below the smallest detectable concentration of 0.003%. Summed predictions for all stems were made using the same technique as was used for biomass summation, the results of which appear in Table 5a.

The results so far presented relate to the existing stand of trees and to the weights of elements which would be removed from the site if the coppice were to be cut and cleared. If to these are added the corresponding weights of materials removed in the singling operation five years ago, the result will approximate the situation which would have existed in 1973 had singling not taken place.

A regression of diameter at breast height on basal diameter was calculated from sample stem values. The basal diameters of stems cut five years ago, as measured on the remaining stumps, were then used in conjunction with this regression to estimate breast height diameters of the stems cut in 1968. Biomass and mineral content of these additional stems were estimated from the regressions previously described and the results are provided in Tables 2a and 5a respectively.

Biomass and mineral content at age 15 i.e. 1961

Discs taken from the sample trees at breast height were used to estimate breast height diameter twelve years ago when the stems were fifteen years old. Biomass estimates for the sample trees at age fifteen were derived from the previously calculated regression of dry weight on diameter and these estimates were used to calculate a regression of dry weight at age fifteen on diameter at age twenty-seven. From the inventory of stem diameters at age twenty-seven, predictions were made of individual stem weights at age fifteen and were summed using the previously described procedures. Results are presented in Table 2b.

Corresponding regressions were calculated for mineral elements and estimates for the fifteen year old stand are given in Table 5b.

In addition to these estimates which relate to stems standing in 1973, it was necessary to make corresponding estimates for the stems which had been cut in 1968 but which would obviously have formed part of the existing stand in 1961.

Estimates of breast height diameters for these stems in 1968 were adjusted to estimate their probable 1973 values using data derived from the sample stems and their dry weight and mineral content at age fifteen were calculated as for the existing stand. These estimates for biomass and mineral content are presented in Tables 2b and 5b respectively.

Discussion

A number of factors have militated against the achievement of accurate estimates of mineral content in the present study. First, since the stand was of an age considerably greater than that for which estimates were required it was necessary to obtain retrospective estimates based on measurements of radial growth. This procedure assumes that relationships between mineral concentration and stem size remain constant with increasing age over a twelve-year period. Secondly the removal of a number of stems five years ago has necessitated several additional stages in computation with a resulting unknown increase in statistical error of estimate. The most reliable estimates are those for biomass and mineral content of the stems presently standing in the wood, those for 1961 and those relating to stems cut in 1968 being less reliable. Ignoring these deficiencies, a crude balance sheet for macro-elements can be drawn up suggesting the probable magnitude of losses from the site resulting from coppice management on a fifteen year cycle as compared with income. Estimates of income to the site in rainfall and aerosols are taken from Meathop Wood (White, personal communication) and relate to a fifteen-year period.

	N	P	K	Ca	Mg	Na
Income (kg/ha/15 yrs)	?	5.2	99.0	130.5	207.0	1689
Losses in coppice removal (kg/ha/15 yrs)	66.4	4.3	25.1	92.1	4.9	2

It appears that removal of minerals from the site in early-spring coppicing is compensated by income in rainfall, though the balance for phosphorus is small. Summer coppicing which involved additional removal in the form of foliage might be expected to result in a negative balance for phosphorus, assuming that expanded leaves contain more of the element than do buds and that the balance is taken up from the soil. Further losses from the site through leachates in drainage water are not considered here, nor are those minerals which become available for uptake as a result of the weathering of parent rock material.

Summary

Estimates of biomass and mineral content were made for a twenty-seven year old coppice stand of oak, ash and hazel growing on a limestone site. Based on these estimates, predictions of biomass and mineral content were made retrospectively for a fifteen year old stand; these suggest that the minerals removed from the site as a result of a 15-year coppice cycle would be replaced by income as rainfall and aerosols and that phosphorus is likely to be the most nearly critical element.

Acknowledgements

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Literature references

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Mountford, M. D. and Bunce, R. G. H. 1973. (In press)

Table 1. Regression statistics for biomass (kg) on diameter (cm)

	a	b	MS	R^2	N
Wt. (g) in 1973 on dbh (cm) in 1973					
Oak	4.598	2.413	0.019	0.992	12
Ash	4.360	2.590	0.027	0.978	12
Hazel	4.723	2.277	0.027	0.975	30
Wt. (g) in 1961 on dbh (cm) in 1973					
Oak	2.833	2.439	0.092	0.886	10
Ash	2.503	2.743	0.191	0.877	12
Hazel	1.421	3.466	0.577	0.690	22

(a) Regression constant; (b) Regression coefficient; (MS) Mean square deviation from regression; (R^2) Coefficient of determination; (N) Sample size

Table 2a. Biomass (kg/ha) of existing stand, 27 years old

		Wt. estimate (kg/ha)	Lower 95% confidence limit (%)	Upper 95% confidence limit (%)
Stems standing in 1973	Oak	15,075	5.6	6.0
	Ash	13,150	6.5	6.9
	Hazel	19,375	2.3	2.3
Stems removed in 1968	Oak	5,050	6.0	6.6
	Ash	10,200	7.8	8.7
	Hazel	75	16.1	19.4

Table 2b. Biomass (kg/ha) of stand when 15 years old

		Wt. estimate (kg/ha)	Lower 95% confidence limit (%)	Upper 95% confidence limit (%)
Stems standing in 1973	Oak	2,825	12.2	14.1
	Ash	3,075	17.4	20.7
	Hazel	5,425	14.4	18.0
Stems removed in 1968	Oak	1,875	12.7	15.3
	Ash	5,700	21.4	29.2
	Hazel	25	82.7	127.0

Table 3. Mineral concentrations (% dry wt.) by sizes and species

	Na	K	Ca	Mg	P	N
<1 cm Oak	0.195	0.220	0.760	0.061	0.059	0.875
Ash	0.012	0.560	0.770	0.081	0.079	0.790
Hazel	0.018	0.200	1.100	0.058	0.067	0.975
1 cm Oak	0.016	0.175	0.555	0.034	0.038	0.580
Ash	0.008	0.310	0.545	0.050	0.042	0.500
Hazel	0.007	0.110	0.580	0.025	0.034	0.555
2 cm Oak	<0.003	0.130	0.560	0.027	0.025	0.410
Ash	<0.003	0.175	0.415	0.033	0.023	0.310
Hazel	0.004	0.063	0.500	0.019	0.020	0.385
3 cm Oak	<0.003	0.130	0.680	0.022	0.021	0.360
Ash	<0.003	0.140	0.395	0.028	0.019	0.265
Hazel	0.003	0.063	0.475	0.013	0.017	0.325
4 cm Oak	0.004	0.094	0.515	0.019	0.016	0.315
Ash	<0.003	0.130	0.320	0.022	0.016	0.225
Hazel	0.003	0.063	0.555	0.015	0.016	0.320
6 cm Oak	<0.003	0.094	0.655	0.021	0.013	0.275
Ash	<0.003	0.112	0.320	0.021	0.012	0.195
Hazel	<0.003	0.078	0.415	0.016	0.016	0.295
8 cm Oak	0.003	0.086	0.475	0.019	0.011	0.230
Ash	0.004	0.110	0.310	0.021	0.011	0.175
>6 cm Hazel	<0.003	0.079	0.340	0.016	0.016	0.280
10 cm Oak	0.003	0.079	0.545	0.015	0.010	0.190
Ash	0.005	0.094	0.220	0.019	0.014	0.165
12 cm Oak	<0.003	0.094	0.490	0.013	0.013	0.185
Ash	0.006	0.104	0.145	0.015	0.010	0.150
>12 cm Oak	<0.003	0.130	0.465	0.013	0.014	0.210
Ash	<0.003	0.110	0.140	0.015	0.010	0.160

Table 4. Regression statistics for mineral weight on diameter

		a	b	MS	R^2	N
SODIUM						
Wt. (g) 1973 on dbh (cm) 1973	Oak	-3.580	2.157	0.219	0.890	12
	Ash	-6.008	2.927	0.571	0.731	12
	Hazel	-4.559	1.819	0.057	0.922	30
Wt. (g) 1961 on dbh (cm) 1973	Oak	-5.065	2.184	0.074	0.886	10
	Ash	-7.785	3.073	0.237	0.878	12
	Hazel	-7.179	2.768	0.389	0.678	22
POTASSIUM						
Wt. (g) 1973 on dbh (cm) 1973	Oak	-1.779	2.201	0.018	0.990	12
	Ash	-1.800	2.450	0.034	0.969	12
	Hazel	-2.132	2.113	0.041	0.957	30
Wt. (g) 1961 on dbh (cm) 1973	Oak	-3.388	2.224	0.077	0.942	10
	Ash	-3.553	2.595	0.171	0.877	12
	Hazel	-5.142	3.185	0.509	0.681	22
CALCIUM						
Wt. (g) 1973 on dbh (cm) 1973	Oak	-0.415	2.336	0.023	0.989	12
	Ash	-0.925	2.411	0.032	0.970	12
	Hazel	-0.281	2.141	0.039	0.961	30
Wt. (g) 1961 on dbh (cm) 1973	Oak	-2.121	2.360	0.086	0.886	10
	Ash	-2.651	2.554	0.165	0.877	12
	Hazel	-3.333	3.223	0.524	0.680	22
MAGNESIUM						
Wt. (g) 1973 on dbh (cm) 1973	Oak	-3.364	2.201	0.026	0.986	12
	Ash	-3.540	2.440	0.030	0.973	12
	Hazel	-3.408	2.022	0.045	0.949	30
Wt. (g) 1961 on dbh (cm) 1973	Oak	-4.978	2.228	0.077	0.886	10
	Ash	-5.286	2.583	0.169	0.877	12
	Hazel	-6.278	3.042	0.466	0.680	22
PHOSPHORUS						
Wt. (g) 1973 on dbh (cm) 1973	Oak	-3.273	2.055	0.022	0.986	12
	Ash	-3.800	2.412	0.034	0.969	12
	Hazel	-3.206	1.983	0.045	0.947	30
Wt. (g) 1961 on dbh (cm) 1973	Oak	-4.778	2.079	0.067	0.886	10
	Ash	-5.535	2.559	0.167	0.876	12
	Hazel	-6.030	2.991	0.444	0.683	22
NITROGEN						
Wt. (g) 1973 on dbh (cm) 1973	Oak	-5.164	2.109	0.024	0.986	12
	Ash	-1.203	2.395	0.031	0.971	12
	Hazel	-0.413	2.027	0.040	0.955	30
Wt. (g)1961 on dbh (cm) 1973	Oak	-2.055	2.131	0.070	0.886	10
	Ash	-2.918	2.536	0.164	0.877	12
	Hazel	-3.300	3.054	0.469	0.680	30

(a) Regression constant; (b) Regression coefficient; (MS) Mean square deviation from regression; (R^2) Coefficient of determination; (N) Sample size

Table 5a. Biomass and mineral content (kg/ha) of existing stand, 27 years old

		Stem wt.	Na	K	Ca	Mg	P	N
Stem standing in 1973	Oak	15075	2.650	15.950	84.525	3.275	2.496	46.150
	Ash	13150	1.110	20.800	45.950	3.550	2.600	33.625
	Hazel	19375	0.975	16.350	108.025	4.025	4.675	80.825
	Total	47600	4.725	53.100	238.500	10.850	9.771	160.600
Stems removed in 1968	Oak	5050	0.997	5.903	29.375	1.215	1.030	17.825
	Ash	10200	0.857	16.193	35.797	2.778	2.027	26.218
	Hazel	75	0.005	0.080	0.513	0.020	0.025	0.410
	Total	15325	1.859	22.176	65.685	4.013	3.082	44.453
	TOTAL	62925	6.584	75.276	304.185	14.863	12.853	205.053

Table 5b. Biomass and mineral content (kg/ha) of stand when 15 years old

		Stem Wt.	Na	K	Ca	Mg	P	N
Stems standing in 1973	Oak	2825	0.575	3.450	16.725	0.700	0.625	10.575
	Ash	3075	0.225	5.225	11.800	0.900	0.675	8.675
	Hazel	5425	0.325	4.820	31.600	1.225	1.425	24.475
	Total	11325	1.125	13.495	60.125	2.825	2.725	43.725
Stems removed in 1968	Oak	1875	0.425	2.400	11.300	0.500	0.450	7.500
	Ash	5700	0.450	9.200	20.500	1.575	1.150	15.025
	Hazel	25	0.003	0.033	0.215	0.010	0.010	0.175
	Total	7600	0.878	11.633	32.015	2.085	1.610	22.700
	TOTAL	18925	2.003	25.125	92.140	4.910	4.335	66.425

Fig. 1. Frequency distribution of stem diameters

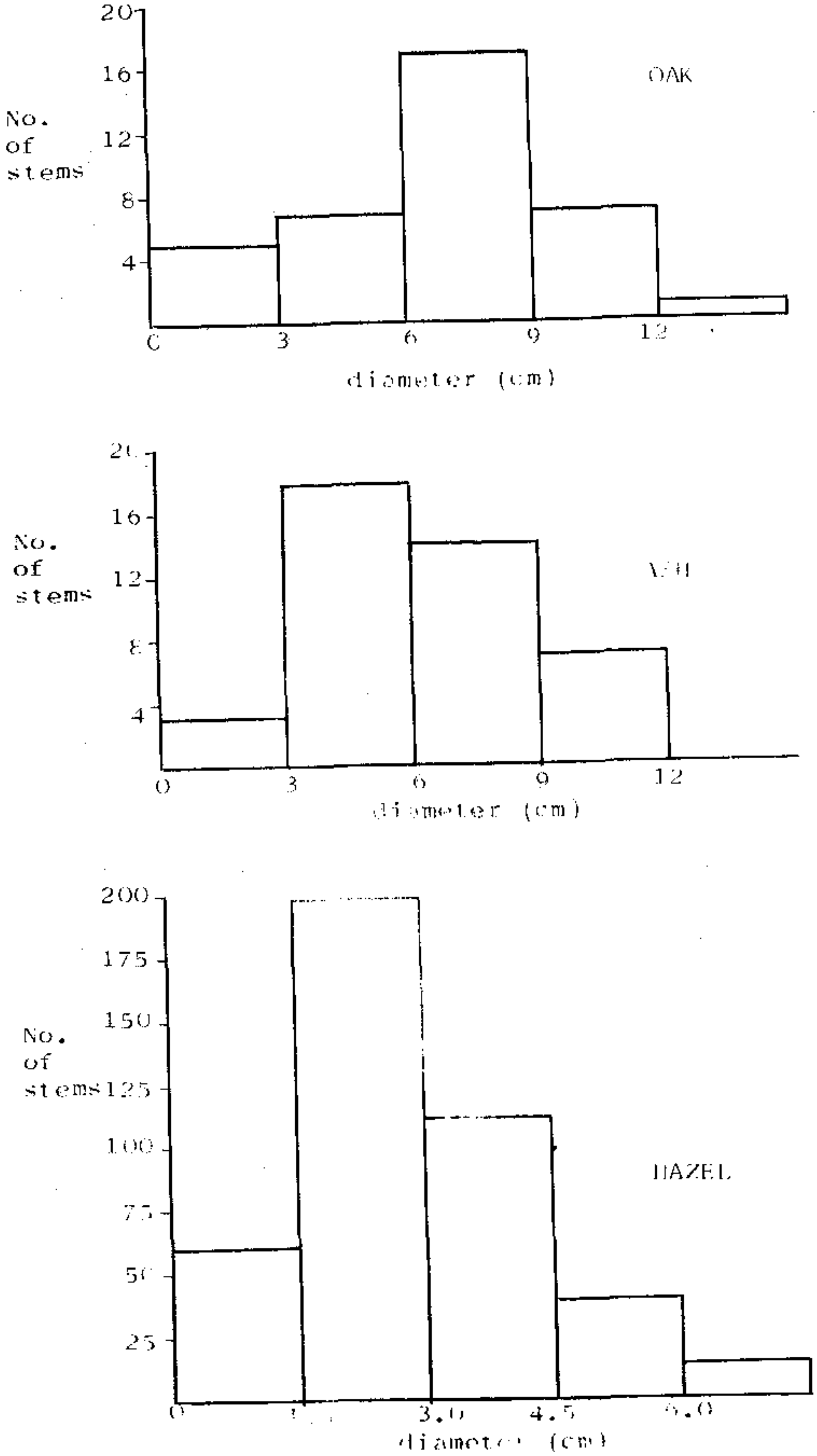
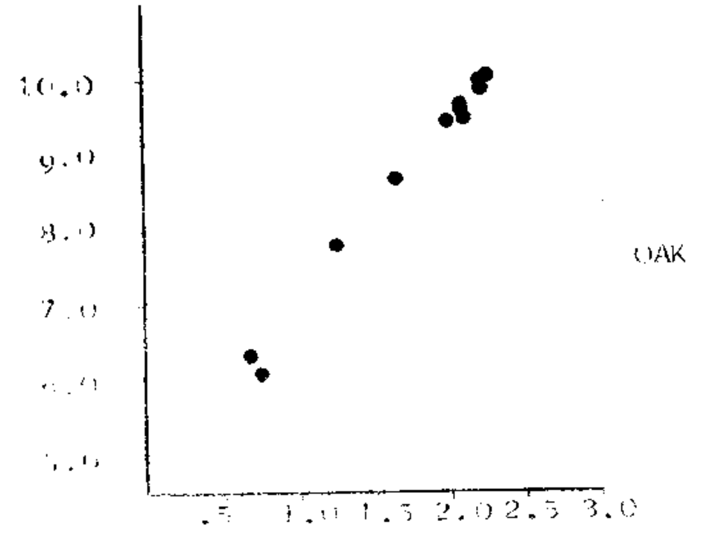
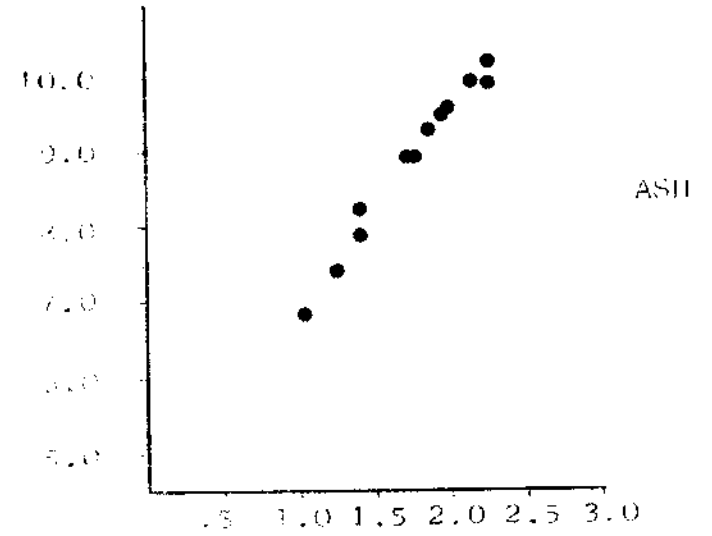


Fig. 2. Scatter diagrams for $\log_e$ tree dry wt (g) on $\log_e$ diameter at 1.3 m (cm)





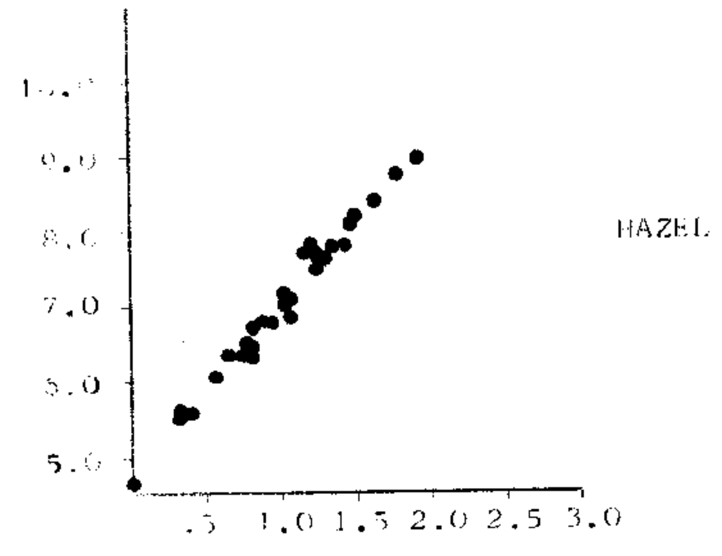
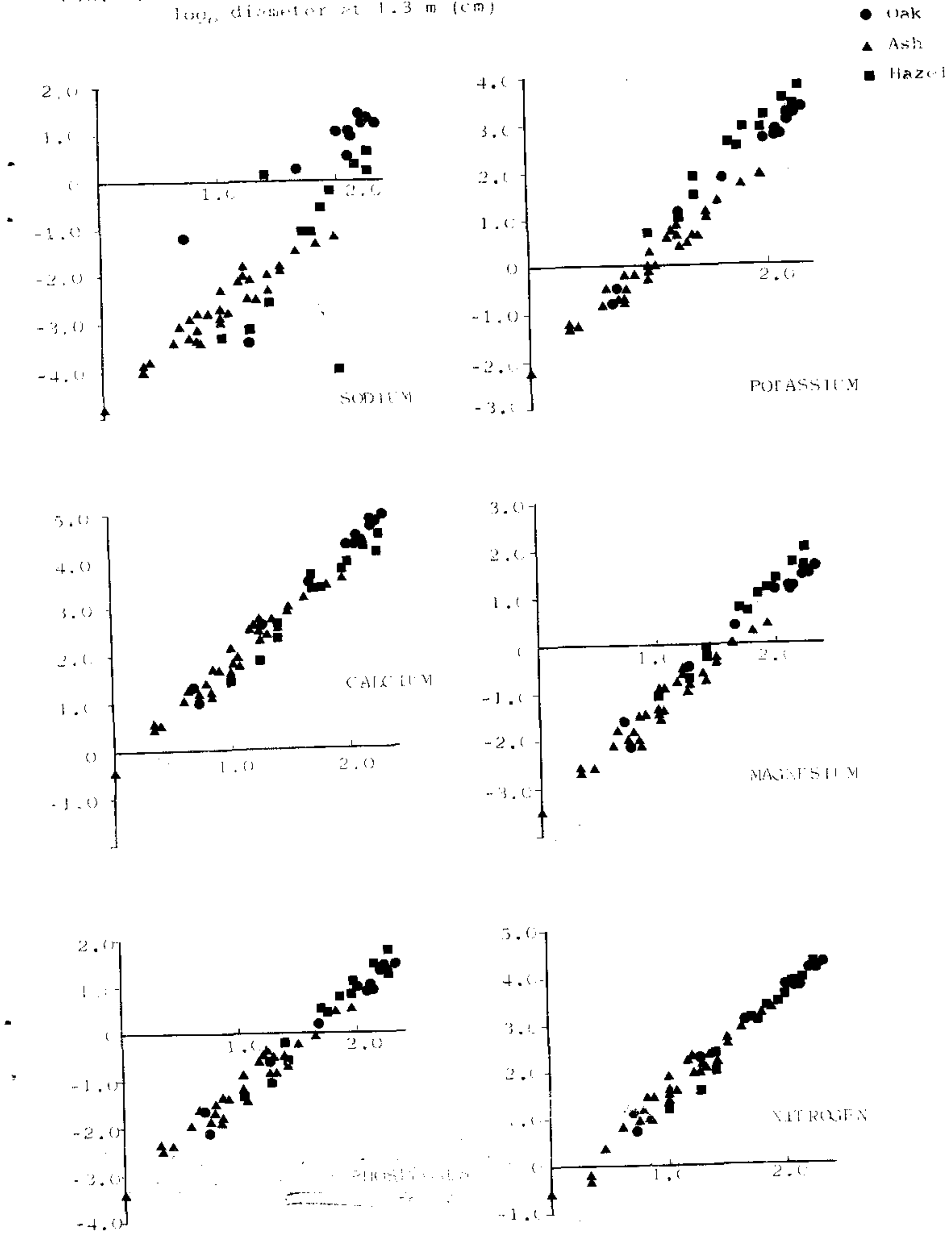


Fig. 3. Scatter diagrams for mineral content (g ha) on $\log_e$ diameter at 1.3 m (cm)



SPECIES LIST

Quercus robur L.
Fraxinus excelsior L.
Betula pubescens Ehrh.
Tilia cordata Mill.
Corylus avellana L.
Rosa spp.
Euonymus europaeus L.
Crataegus monogyna Jacq.
Prunus spinosa L.
Mercurialis perennis L.
Rubus fruticosus agg.
Arum maculatum L.
Viola riviniana Rchb.
Anemone nemorosa L.
Urtica dioica L.
Endymion non-scriptus (L.) Garcke
Asperula odorata L.
Orchis mascula (L.) L.
Convallaria majalis L.
Fragaria vesca L.
Teucrium scorodonia L.
Dactylis glomerata L.
Brachypodium sylvaticum (Huds.) Beauv.
Melica uniflora Retz.
Bromus ramosus Huds.
Carex sylvatica Huds.
Dryopteris dilatata (Hoffm.) A. Gray
Mnium hornum Hedw.
Hypnum cupressiforme Hedw.
Brachythecium rutabulum (Hedw.) B. & S.
Isothecium myosuroides Brid.
Leucobryum glaucum (Hedw.) Schp.
Dicranum scoparium Hedw.
Thuidium tamariscinum (Hedw.) B. & S.